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Quantifying spatio-temporal patterns of urban expansion in Beijing during 1985–2013 with rural-urban development transformation

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ABSTRACT

Rural-urban development transformation has entered a crucial period with the development of urbanization, informatization, industrialization and agricultural modernization. Quantifying spatio-temporal patterns of urban expansion is essential to monitor and assess the process of urbanization and offer a theoretical basis for rural restructuring and landscape dynamics. In this paper, we used the remotely sensed land use data to quantify and research spatio-temporal patterns of urban expansion from 1985 to 2013 in Beijing, China. This study integrated methods of statistical analysis (i.e., calculation of time series landscape matrices and urban expansion index) and the gravity-center model to study the landscape configuration, the holistic change of urban land in area, size, expansion speed and movement direction, respectively. Meanwhile, GIS-based buffer analysis was also applied to study the spatial mode of urban expansion in Beijing. Results demonstrated that (1) Beijing has experienced magnificent urban sprawl in the last 28 years. The combination of time series landscape matrices exhibited a typical spatial configuration of urban sprawling in Beijing: leapfrog development of new urban nuclei formation in areas which were non-adjacent to existing urban centers with obvious fragmentation, as well as expansion of existing urban areas resulting in contiguous urban entities in each time interval; (2) The gravity center of urban land continued moving northeastward, except during the time intervals of 1995–2000 and 2010–2013 when it moved southward; (3) The northern fan-shaped suburb was the most active area of urban expansion before 2005, and urban later had a concentrated expansion toward the southern inverted-triangle-shaped area; and (4) Urban sprawl presented denotative features along the motorways, while urban also expanded in the form of a big pancake.

1. Introduction

Rapid urbanization occurs along with the fast growth of urban population (Li et al., 2013). During the decades of Reform and Opening-up Policy beginning in 1978, urbanization in China has been taking place at an unprecedented rate (Bai et al., 2014; Liu and Yang, 2015). This rapid development of industrialization and urbanization has promoted regional economic development and improved the international competitiveness and also deeply influenced the vast rural areas and affected the transformations of regional rural-urban relationships and industry-agriculture relationships (Liu et al., 2010b). This has brought great changes to agricultural production patterns, rural industrial structure, consumption structure and employment structure (Liu, 2007). Currently, rural-urban development in China is on the key phase of social and economic change as it is undergoing a crucial transition period with a shift in the economic balance and the widening of urban-rural wealth gap (Liu et al., 2008, 2012; Long et al., 2007, 2010; Lu et al., 2013). Rural-urban development transformation refers to a complex human process of mechanism transformation, strategy change and elements transfer between urban and rural areas in the new period of China (Liu and Yang, 2015). Accordingly, the above processes have influenced the social, economic and environmental pattern in China's urban and rural areas. Critical trends have appeared including massive rural out-migration (Liang et al., 2002), the growth of urban expansion, the depletion of arable land and the loss of rural settlements in peri-urban districts (Liu et al., 2010b; Long et al., 2009, 2012; Wang and Scott, 2008; Wei and Zhao, 2009), which are very prominent considering the accumulation effect of urban land-use change in China (Wang et al., 2012; Wu et al., 2006; Yang et al., 2011). Given the profound effect of urbanization on rural depopulation, rural-urban migration, rural transformational development, rural sustainability and rural restructuring during the rural-urban transformation period (Liu et al.,

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2009, 2010b; Long et al., 2011; Weekley, 1988), it is fundamental to characterize the changing patterns of urban growth to solve the related issues. Quantifying spatio-temporal patterns of urban expansion is essential to monitor and assess the process of urbanization (Inostroza et al., 2013; Jiang et al., 2007; Liu et al., 2010a; Tan et al., 2005; Xu and Min, 2013), thereby offering a theoretical basis for rural restructuring and landscape dynamics and also an important foundation for researching the characteristics of rural-urban development transformation such as the rural settlement loss and arable land depletion under rapid urbanization (Liu et al., 2017).

Arguably, urbanization is the most significant form of land use change (Seto and Fragkias, 2005) and it has inevitably resulted in a large-scale and wide range of various effects on the structure, function, and ecosystem dynamic. This shift is especially substantial and rapid in Beijing, the capital city of China (Gu and Shen, 2003). Before 1949, the urban area of Beijing was mainly confined to the area within the old town, which is currently marked as the 2nd Ring Road with a low urbanization rate. Beijing, serving as the political, economic, cultural and educational center as well as being the most important center in China for international trade and communications, has been expanding modestly after the founding of the People's Republic of China. Urban expansion of Beijing began to accelerate after the Chinese economic reform in 1978, bringing massive encroachment into the surrounding countryside (Wu et al., 2006). Beijing has already faced with a severe situation of been confronted with increasingly serious environmental pollution, congested traffic, and insufficient water supply due to immigration. Particularly, the fast city expanding has caused the loss of a great deal of agricultural land in the alluvial plain area of Beijing and profoundly affected the neighboring rural landscape. Considering that urbanization will continue to be an important part of the global environment change in the near future, it is necessary to understand and characterize the dynamic patterns of urban expansion (Seto and Fragkias, 2005).

Based on remotely sensed data, research in the fields of urban geography, modeling and ecosystems has been widely conducted in the study area of Beijing (He et al., 2008, 2011a,b; Jiang et al., 2007; Li et al., 2005, 2013; Wu et al., 2006; Yang et al., 2011; Zhao, 2010; Zhao et al., 2009). The physical process of urbanization in Beijing is most commonly analyzed as either a measure of area change extent or a measure of change rate from non-urban land to urban uses. Yet, aggregate growth rates often provide limited information regarding spatial patterns of urbanization or the underlying processes that shape urban areas as these research are mainly from the macroscopic and static perspective. The spatial configuration of urban landscapes is also as much a reflection of past as it offers a snapshot of current socio-economic processes and interactions (Seto and Fragkias, 2005). Therefore, there is a need to combine these various methods to character the process of urban land-use change, which not only limits the research of macroscopic perspective (i.e., the quantitative structure and layout pattern) and also study in a micro perspective to effectively quantify the dynamic process of urban land-use structure and fully understand the complete inner structure and land use characteristics.

This research accordingly aims at contributing to the analysis of dynamic urban expansion by focusing on the spatial-temporal characteristics of urbanization through comprehensive application of multiple methods, which will offer the basis of studying rural-urban development transformation. After integrating methods of statistical analysis (i.e., calculation of time series landscape matrices and urban expansion index), gravity-center model, and GIS-based buffer analysis, the paper researches the spatio-temporal patterns and spatial mode of urban expansion in Beijing in detail. Urban landscape configuration could be a reflection of the past to some extent as the spatial distribution of urban land offers a snapshot of a wide variety of social, economic, and political factors which affected land use changes. Thus, the objectives of this present study are (1) to research the spatial-temporal characteristics of urban expansion from 1985 to 2013, such as the overall extended area, size, expansion speed and movement direction; (2) to analyze spatial distribution structures and interior differentia of urban land; and (3) to explore spatial modes of Beijing's urban expansion in the last 28 years. These results will provide the basis for our further research of effects of urbanization on rural transformation, especially on rural out-migration, rural restructuring, coordinated urban-rural development, farmland protection and food security guarantee and other issues related with rural-urban development transformation.

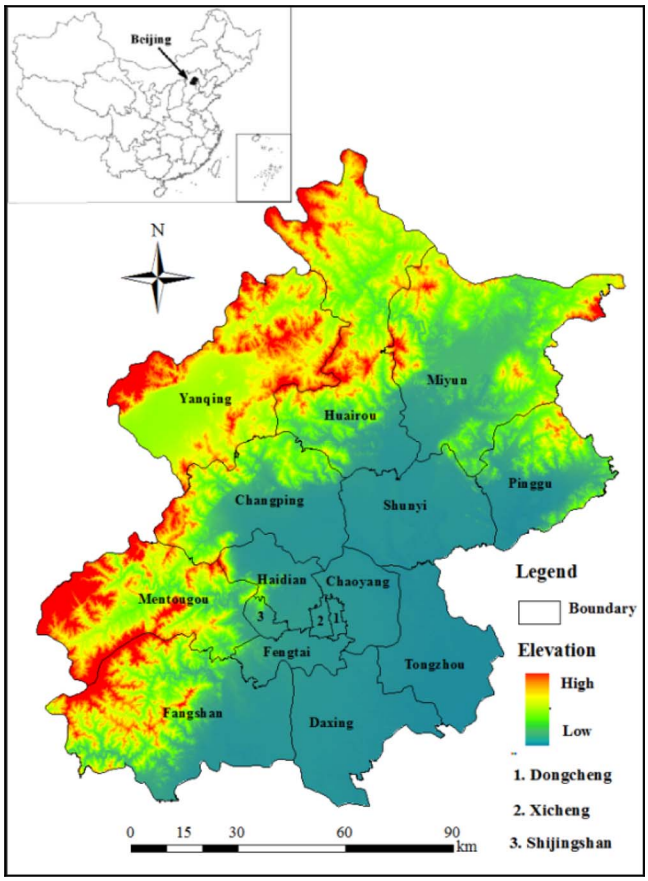

Fig. 1. Map of the study area.

2. Materials and methods

2.1. Study area

Lying in the northeast of northern China Plain, Beijing (N39°28′-N41°25′, E115°25′-E117°30′) (Fig. 1) has great topographic variation. Roughly occupying 62% of the total area, most of the mountainous areas are located in the northern and western areas while the plain covers 38% of the total area and is located in the central and southeastern area (Li et al., 2013). The “Beijing Plain” is the main area of urban expansion (Li et al., 2005). Beijing consists of fourteen districts (Dongcheng, Xicheng, Chaoyang, Haidian, Fengtai, Shijingshan, Tongzhou, Mentougou, Fangshan, Changping, Daxing, Shunyi, Pinggu, and Huairou), and two counties (Miyun and Yanqing) after the latest administrative division adjustment in 2010.

2.2. Data

Based on the available data in the study area, monitoring of urban expansion of Beijing was done at five time nodes: 1985, 1995, 2000, 2005, 2010, and 2013. We collected the multi-temporal remote sensing images (Landsat-TM), used artificial visual interpretation to obtain the land use and land cover (LULC) map in each time node (Fig. 2) and then